World food security, globalisation and animal farming: unlocking dominant paradigms of animal health science

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Summary
This paper presents a critical review of intensive animal farming in the light of past and present global crises, reflecting the fragility of its foundations, its unsustainability and its inability to ensure world food security. A central argument of this paper is that intensive animal farming promotes industrial efficiency, commodity production and the availability of cheap food at the expense of farmed animals, the environment and society. This paper begins by briefly examining the history of world food security and explores the role assigned to animal farming, animal health and public health in this context. It then reviews changing perceptions of world food security during various periods of global instability and their implications for animal farming and animal health and welfare. At the same time, the paper seeks to identify what has so far been missing in discourses around world food security and animal farming, and discusses how these gaps shape and are shaped by specific scientific thinking on animal health and well-being. With the recent exponential growth of aquaculture, the authors' objectives are to examine animal health practices in farming and to understand how animal health science could effectively, in the long term, help animal farming, and in particular aquaculture, to contribute to global food security.

Keywords
Animal health science – Animal production – Aquaculture – Farming – Food production – Food security – Global food security – Globalisation – Sustainability – World food security.

Introduction

The estimate that food production must increase by 50% to meet rising demand by 2030 and double by 2050 to feed a future world population of nine billion represents a central pillar of the debate surrounding world food security (1, 2). At the same time, the Western diet, characterised by its high content of meat, fish, dairy products and vegetable oils, has become a worldwide symbol of prosperity and economic growth, as well as an aspiration for newly urbanised countries (3). In this context, animal products (i.e. terrestrial and aquatic animal products) have become key elements of the food security framework promoted by the food industry worldwide (2, 4). In the last 50 years, world animal production has almost quintupled and this trend is expected to continue (4, 5). In particular, the amount of fish obtained by aquaculture has increased from 4.7 to 66.6 million tonnes in just 32 years (6).

However, in practice, animal production systems today face considerable pressure and increasing opposition, at least in the global North (1). Public debates on the damage caused by animal farming to the environment have increased, as well as concerns over cancer, obesity and diabetes from the consumption of red meat and high-fat foods, such as dairy products (2, 3). Despite their success since industrialisation in the 1960s, animal production systems have also proved extremely fragile (7, 8). Since the 1980s, they have been prone to numerous public health crises and food scandals, such as the 'mad cow' crisis in the 1980s (9); the contamination of chicken, beef, pork, dairy and farmed salmon products with dioxins (10, 11); the emergence of influenza in the pig and poultry sectors (12,

13); and, more recently, the horsemeat scandal (14). For the most part, these crises have been linked to intensive animal farming and its dynamics.

The risks and uncertainties generated by these events have triggered many public debates on intensive animal farming. worldwide and increased fears about the future of food production, food security and health (15). Questions such as 'how healthy is our food system?', 'what kind of Earth will future generations inherit?', 'are any foods safe to eat any more?', and 'how do we feed a growing global population?' have become commonplace in public, academic and political circles and highlight a common aspiration to healthier, more environmentally friendly, ethical and sustainable systems of animal production worldwide (8, 16, 17, 18).

In this paper, the authors begin by briefly examining the history of 'world food security', a concept adopted by the World Food Summit in the late 1990s, and explore the roles assigned to animal farming and human and animal health in this context. The paper reviews changes in the perception of world food security during various periods of global instability and the implications of these changes for animal farming, farmed animals, and global health and well-being. At the same time, it seeks to identify what has so far been missing in the discourse around world food security and animal farming, and discusses the ways in which such gaps shape and are shaped by specific scientific thinking on animal health and well-being. In doing so, the authors' objectives are to examine animal health practices in farming and understand how animal health science could effectively, in the long term, assist animal farming to contribute to global food security.

In particular, this paper aims to stimulate debate around the development of the aquaculture sector: how to avoid the problems that can occur when a sector becomes a major component of the food system, and how to ensure that it continues to contribute positively to sustainable world food security.

World food security and the globalisation of animal farming

Food is essential to all living beings and its shortage has always been a concern for humans. On the other hand, the need for humans to anticipate and secure a global food supply in the long term, taking into account the fact that the world's resources are limited, is more recent. Colonisation and human development have contributed to an awareness of this problem ever since, in 1798, Thomas Robert Malthus predicted that the growth in human population would soon supplant world food production (19). More than two centuries have now passed and the 'neo-Malthusian' argument about world food security, i.e. that more food must be produced to feed more people, still dominates (2). Yet the world food situation has dramatically changed in recent decades, challenging this traditional approach to world food security. The following sections present the evolution of the concept of world food security during the 20th century and its implications for animal farming and health.

The history of world food security and the political choices of globalised animal farming

The issue of food supply first emerged into the international political arena in the early 1930s, when consumer purchasing power and primary producer income were dramatically affected by the global financial crisis and the 'Great Depression' (20). At the same time as so many were thrown into poverty, advances in the science of nutrition revealed that acute hunger and malnutrition had harmful long-term effects on health. In this context, the League of Nations concluded that, by rationalising food production, supply and trade through intergovernmental agreements, producers and consumers could be protected from market price fluctuations and food surpluses could be sent to poor and 'needy' countries in the global South (20). The vision was clear and strong: 'increasing food production

to meet human needs would bring prosperity to agriculture, which would overflow into industry, and bring about the needed expansion of the world economy' (20).

The outbreak of the Second World War interrupted this first initiative. Nonetheless, only a few years later, this vision of a global triad between health, agriculture and economic policy resumed. In 1943, 44 nations met in a United Nations Conference and decided to create the Food and Agricultural Organization of the United Nations (FAO). Their principal aim was to achieve what, in 1941, President Franklin D. Roosevelt had identified as one of the 'four freedoms of man': the 'freedom from want' (20). (The other three are: 'freedom of speech and expression', the 'freedom to worship God in his own way' and 'freedom from fear'.)

The Second World War caused vast disruption to agricultural production, trade and distribution. After it ended, food supply and, more specifically, self-sufficiency were major concerns in many countries of the Northern Hemisphere, and many initiatives, such as subsidies and grants, were undertaken by governments to support farm production and to reinforce the agricultural sector. The trauma caused by severe food deficiencies during and after the war and the balance sheet of the global food situation as stated by the FAO in 1946 (i.e. that 'there were not enough *calories* produced on Earth for everyone to be well fed') were important incentives for many European countries, as well as the United States of America (USA) and Canada, to increase domestic food production (20).

In this context, these governments supported major programmes for agricultural research and extension, alongside price support policies that had been developed during the war. In the USA, such policies supported crops and livestock products with the intention of guaranteeing good incomes for farming communities, increasing production and boosting the national economy (20).

At the international level, major advances in crop sciences were being driven by the pioneering work of Norman Borlaug, which contributed to the 'first green revolution' and played a role in the creation of the Consultative Group of International Agricultural Research (21). However, with advancing technology and industrialised farming methods, production outpaced demand, leading to serious surplus problems. This was particularly the case for animal production, which was encouraged by governments through price support programmes (subsidies or price controls) (20). Partly for this reason, food aid became the tool used by the global North to fight world food insecurity in the global South (20). In 1960, the General Assembly of the United Nations voted for a new resolution on 'the provision of food surpluses to food-deficient peoples through the United Nations System', which marked the starting point of the World Food Programme. This way, domestic food surpluses could be stored and used for multilateral development, thus countering excessive price fluctuations while also fighting hunger and world food insecurity (22).

However, the status of the world food reserve varied according to global production and demand, and was also influenced by environmental (e.g. climate) and economic (e.g. the price of transport) factors. For instance, in the 1970s and between 2007 and 2008, due to poor weather conditions, many countries became importers of cereal, reducing the world food reserve to its lowest level since the 1950s. Since this coincided with an increase in oil prices, affecting both production and transport, cereal food prices increased dramatically (20).

It was only in 1996, at the World Food Summit, that the United Nations officially recognised the importance of food access as a food security issue. The issue of world food security involved, therefore, not just the *amount* of food to be produced, but also the opportunity for the poor to *access* it. World food security could only exist when 'all people, at all times, would have physical, [social] and economic access to sufficient, safe and nutritious food which would meet their dietary needs and food

preferences for an active and healthy life' (23). (Note, the term 'social' was added to the 1996 definition in 2002.)

This definition contains many essential elements for the analysis of world food security. In particular, it sheds light on how animal production systems and animal health have been shaped by discussions around world food security. The next section explores the ways in which animal farming has been designed to contribute to world food security and analyses the sustainability of the suggested agricultural model. By taking this approach, the authors' aim is to identify which elements of the food security definition set out by the World Food Summit can be more fully met by improving the application of animal health science.

Globalisation and the development of intensive animal farms

After the Second World War, the concept of world food security depended on the idea that producing more food – and, at the same time, increasing production outputs, industry profits, the national gross domestic product per capita and the purchasing power of consumers – would be socially beneficial for everyone.

In this productivist framework, farmed animals and their environment were used as capital to produce outputs (e.g. meat, milk, eggs) that had greater market value than the inputs (e.g. cereals). In addition, the animals' exchange value (i.e. the quantity of other commodities that they would be exchanged for, if traded) had to continually expand. Hence, the term 'live-*stock*' for animals that are domesticated for food production. In other words, farmed animals and their products became capital, internationalised and globally regulated, to easily circulate through complex global networks of production, trade and finance (24, 25).

As a result of their continuing upward movement, the prices and profits of animal products could be equalised worldwide and resource allocation for their production (e.g. feed, technologies) could be shared between countries. In being *global*, as opposed to international, patterns of animal production and consumption became integrated across territories without regard to the particular context in which they were located. As a result, new forms of organisation and new structural arrangements had to be found for animal farming to remain competitive globally and for associated global and local enterprises to survive (25).

To achieve the food production goals set by governments, farming had to change drastically. In the 1960s–1970s, a new industrial model of farming initiated by the USA expanded into Western Europe before reaching developing countries and, to some degree, Eastern European countries (25, 26). Research institutes (for example, in agronomy, animal breeding and nutrition, horticulture and engineering) and the booming manufacturing industries were the key pillars of this new 'agricultural extension model', which promoted the use of industrial methods and technologies in farming (27). These included the development of new crop varieties, animal breeding techniques and genetics, as well as the use of fertilisers and machines (e.g. reaping machines, tractors, and transportation) that raised productivity (26). Small-scale, family-oriented farms began to disappear, and animal farms were integrated into the wider dynamics and complex networks of industrialisation and capital accumulation.

Moreover, animal farms expanded in size and were transformed into factory-based industries, where on-farm activities could be easily mechanised, harmonised, rationalised and intensified (26). As a result, farmers became compelled to follow the *logic* of the food industry, including managing the pressure on prices applied by complex, global, food-producing and processing chains (26). As intensive

systems of production expanded the production capabilities of farmers, their products and prices became increasingly competitive, as demand from growing and prosperous cities increased (26).

The globalisation of farming and the technological advancements of the time also played an important role in geographically liberating individual capital units (e.g. animals), as these were shifted to regions with lower production costs or behind tariff walls (25). The integration and benefits of conventional farming methods, however, varied considerably among farmers and countries, excluding many from the global food industry system. Important differences existed between and within countries in terms of research and development capacities; access to technologies; investment funds; communication between scientists, industries and farmers; and natural resources (27). The inability of some governments to adopt conventional models of animal farming and to promote their own interests (i.e. the interests of their populations, including farmers, retailers and consumers) also resulted in several episodic structural crises that disrupted, and continue to disrupt, the economic, social and political conditions under which food is produced and accumulated globally (26, 28). The following section examines, in particular, the contradictions, dilemmas and tensions that followed the globalisation of animal farming in relation to human and animal health.

Bridging the divide between the globalisation of animal farming, consumption and health.

Since the end of the 19th century, successive 'food regimes' (i.e. global political choices around food production and consumption) have each marked a milestone in the modernisation, globalisation and use of animals in the food industry. The 'first food regime' (1870–1930s) was based on colonisation and capitalisation of land and raw materials in the 'New World'; the second (1950s–1970s) had the objective of redistributing food surpluses from intensive agriculture and animal production, while expanding the monopoly of capitalist markets and encouraging, or claiming to encourage, the industrialisation of the global South (29, 30). Since the 1980s, new rising powers, such as China and Brazil, have been integrated into the global food chain, suggesting that a 'third food regime' has emerged while, at the same time, consolidating the productivist model of the food industry (30). The increasing globalisation of the food industry was accompanied by a rapid rise in the number of supermarkets in many parts of the world, changing the way that animal products are produced, distributed and consumed, and causing rising tensions between the local and global food economy (31).

Different crises and debates around the environment, global warming and energy scarcity have raised important questions about the sustainability of contemporary food regimes and their harm to society (29, 32). In this context, livestock have often been identified as a source of problems (e.g. of greenhouse gas emissions, pollution and risks to human health) and their keepers and carers (e.g. farmers, farm technicians, veterinarians) are seen as responsible. Some ecological movements, for instance, are calling for the removal of animals from the global food chain or significant reductions in their numbers, and the professional transition of farmers and other animal-farming professionals (2, 32). It can be argued that, since the 1950s, farmed animals have been treated by the food industry as mere material artefacts, i.e. objects created by the industry to produce and generate more profits in human and urbanised societies. In this way, animal health and the risks associated with animal farming have become monopolised by the food industry and the city (as opposed to the rural countryside). By rethinking the status of farmed animals and the role of animal agriculture in society (i.e. their place, their representation, and their health) and linking these ideas to the dynamics of the food industry and urbanisation, new ways of thinking about animal farming, animal health, public health and world food security could emerge.

From a productivist to a post-productivist regime of animal production

In the 1950s, governments developed and implemented policies to increase agricultural output per unit of land, of terrestrial livestock and/or of labour, with no consideration of their impact on the environment, domesticated animals and society. These policies not only changed the organisation of rural areas and farm production units, but also transformed farm occupations. Agricultural production increased rapidly, due to farm mechanisation and government incentives (e.g. supported research and farm subsidies), which helped to expand the dairy, livestock and arable industries while simultaneously reducing the total area used for animal grazing. The number of livestock farms decreased, but average herd and flock size increased, as did production per head (33, 34).

In the United Kingdom (UK), the total number of dairy farms fell by more than 50%, to fewer than 14,000 from the mid-1990s, and the number of dairy cows decreased by about 27% to approximately 1.9 million. Yet, average milk yield per cow has increased by 93% since 1975, allowing domestic milk production to increase during the same period (34). Similarly, in just 50 years, the US broiler industry evolved from fragmented and local businesses to nationally integrated businesses. This process included vertical integration of feed mills, hatcheries, farms and processors, which made the poultry industry more efficient, responsive and profitable.

Productivity gains have been made through increases in livestock density (i.e. the number of animals kept and raised per square metre) and animal carcass weight at slaughter (35). In this context, different processes of industrialisation, scientific progress (e.g. genetics and nutrition) and technological innovations (e.g. drugs and fertilisers), supported by governments (e.g. subsidies on chemical inputs), became instrumental to increasing animal and farm productivity (36). In particular, drugs such as antimicrobials and anthelmintics became key to maintaining health and promoting growth in terrestrial livestock raised under particularly demanding conditions, thus helping to increase the global availability of cheap food (33).

However, concerns raised over the degradation of landscapes, the environment (e.g. global warming, water pollution and decimation of wildlife), and consumer health (e.g. food toxicity and antimicrobial resistance) have led to a progressive call for a fourth 'post-productivist' food regime that could promote ethics and sustainability in animal farming (37, 38). The 2006–2008 food crisis and competing demands for crops from a burgeoning biofuel industry have also led to significant changes in thinking about terrestrial livestock farming, and the need to rethink agricultural territories and animal protein production (39). In this context, aquaculture systems have become the new hope for the food industry and seafood an increasingly important source of animal protein for society.

This change has been rapid. Aquaculture now represents the fastest-growing animal farming industry, exceeding the contribution of marine seafood harvesting to world protein and nutrient supplies in 2014 (40, 41, 42). In the early 1990s, this relatively new sector was seen as one of unlimited possibilities, with little social or public resistance to its emergence, all of which contributed to the globalisation of aquaculture (41). Yet, aquaculture has already spread intensively to new areas of activity, at the expense of the local community (e.g. the indigenous community) and other non-conventional, national and international producers, such as subsistence and organic farmers, without due consideration of the environmental and health risks that were previously identified in the terrestrial livestock sector (43).

A global culture of consumption and health

Despite industrialised and globalised farming's major success in producing cheap and accessible foods of animal origin for society, there is a fragility to these production systems that is rarely acknowledged or explored. In recent years, the particularly demanding conditions under which intensive farming

operates have driven the emergence of new pathogens and production diseases, such as mastitis (i.e. udder inflammation) and lameness in cattle (44).

The increase in animal density, the shortage of rearing areas, and the need to share land among different animal species (i.e. domestic and wild) have created ideal conditions for the development, transmission and spread of parasites such as helminths in cattle and sheep (e.g. gastrointestinal nematodes and liver fluke) (33), and sea lice in farmed fish (45). Moreover, bacterial infections, such as necrotic enteritis, coccidiosis and *Escherichia coli* infections, have become increasingly common due to factors such as increased animal density, breed and growth selection, and changes in diet that have altered and disrupted the intestinal flora of animals (46, 47). Finally, the increase in the volume of animal transport, linked to the complexity of industrial networks, the specialisation and division of labour, the search for optimisation and the distance between various actors in the food chain (e.g. farmers, processors and retailers) has favoured many stress-induced and respiratory diseases (48, 49). Changes in animal farming, as was to be expected, have disrupted the natural balance that tends to exist between the environment, animals and pathogens, driving disease emergence and creating many more animal health problems (50).

Importantly, the globalisation of agriculture and the large-scale international movement of animals and their products have also turned the rather local nature of these issues into real global concerns. These include strictly commercial concerns, as well as public health issues, although the two are related since economic development affects and is affected by public health (51). In the 1980s, the bovine spongiform encephalopathy (BSE) crisis was the first to highlight the risks associated with intensive farming, globalisation and low-cost practices in the food industry (9). Other examples soon followed, such as the contamination of food products with dioxins in Europe; outbreaks of infectious salmon anaemia, salmonella, and listeria; the 2001 foot and mouth disease crisis in Britain and increasing public health concerns over drug resistance and the medicalisation of terrestrial and aquatic livestock farming (10, 52, 53, 54).

All these cases underline the numerous health risks associated with globalised and intensive animal farming (for both humans and other animals), shedding light on the 'true cost of cheap food' (55). Among the issues raised are food affordability, weaknesses in global food governance and regulation, and gaps in food traceability, due to globalisation and highly complex food chains. Yet, in all the public health debates triggered by these events, the status of domesticated animals in society was only rarely discussed (52), and certainly such discussions never ventured far beyond narrow anthropocentric views on the well-being of farmed animals.

The productivist logic of conventional systems has shaped the dynamics of animal farming and the health and welfare of farmed animals. It has also determined which species are farmed, influencing human dietary diversity, as well as the nutritional content and taste of human food (56). Judged by their habitat, diet and vulnerability to hazards, as well as by various physical, olfactory and visual criteria, some animal species have been promoted by the food industry and others not. The 'chosen' species have been – and continue to be – those that are easier and cheaper to rear, process, trade and promote, and are therefore more profitable for the food industry. In the aquaculture sector, for example, the need for advanced technology to feed fry (newly hatched fish) and the problem of cannibalism in cod farming partly explain why growth in this area has been slower than that of Atlantic salmon in Norway (57). More generally, the chicken broiler industry and some farmed fish (e.g. Atlantic salmon, tilapia and pangasius) have, for the same reasons, experienced exponential growth worldwide (40, 58). In this way, these much more 'convenient' and 'profitable' food products have become the main components and source of nutrients on human plates.

The industrialisation and intensification of animal farming has reduced the cost of foods of animal origin and contributed to the gradual development of mass consumption. Over the years, consumption expenditures have declined and patterns have shifted towards supermarket processed foods and 'fast food' (25). The composition and nature of human food have therefore changed dramatically and become 'more and more mediated by corporations' from the food industry (58). At the same time, by deliberately manipulating staple ingredients, such as salt, sugar and fat, to avoid product deterioration, allow global distribution and increase food palatability, the food industry has also contributed to the emergence of new public health concerns, such as diabetes and non-communicable diseases (e.g. heart disease and obesity) (59, 60).

Rethinking dominant paradigms of animal health science

Conventional animal farming has been driven by the adoption and adaptation of technologies to use resources more efficiently in a context of unlimited resources (largely land and water) and unlimited demand, leading to greater yields and profits (56). In this way, world food security and animal farming have focused on *quantity*, i.e. on maximising the production of calories and nutrients through technology, with smaller niche markets satisfying *quality*. Animal farming has become focused on commodity production, especially in the poultry and aquaculture sectors, which have lower feed conversion ratios than ruminants and pigs. This is one of the main reasons why global production of farmed chicken and seafood products has expanded so rapidly in recent years, and it is a model that relies on cheap feed grains and oilseed cakes. Moreover, seafood products have the advantage of high levels of vitamins, minerals, essential fatty acids and high-quality proteins, making aquaculture a significant hope for world food security (41).

However, these apparently beneficial outcomes need to be balanced by the well-known and documented effects of intensive animal farming on the environment, animal health, food quality and justice. The response has been visions of animal production systems that are local, traditional and less technological, with the objectives of being healthier, more sustainable, and better for society. These are presented as being more capable of ensuring world food security (56), with a message that, rather than quantity, 'unconventional' models of food production focus on the quality of the farming and the food. Yet, world food security requires us to find the right balance between quantity and quality (56).

Although it is widely accepted that animal diseases have a negative effect on animal welfare and food system productivity, there is a lack of knowledge of the magnitude of these effects (61, 62) and their implications for food quality. The production of scientific knowledge is particularly restricted by the use of limited tools (e.g. feed conversion ratio and serology) and single quantitative approaches that are based on mere observation of associations between production predictors and disease outcomes (63).

Indeed, animal health science has traditionally focused on the elimination of animal diseases as a strategy for producing more food, without delaying industrial production cycles (64). Under this model, the multiple reasons for animal health science, i.e. that it not only protects animal health and well-being but is also vital for human health and wellbeing, have been reduced to a single technical and economic purpose (65): to increase food production and keep pace with the growth of the world's human population, while ensuring market stability and industrial monetary income. In this context, animal health science has focused on the technical exploration of the biology of animal diseases through the development and use of new technologies, such as diagnostic tests, drugs, vaccines, robotics and improved infrastructure, without grasping the complexity of social, political, cultural and economic determinants of animal health (33). Such an approach is based on dubious scientific incentives and a relatively illusory and certainly incomplete view of what sustainable animal farming means and how to achieve world food security.

These reductive scientific approaches do not allow animal health scientists to decipher the complexity of animal diseases and infectious processes in farming (33, 61, 65) and farmed animal care. The lack of informed lay (as opposed to expert) participation (e.g. of farmers) and relevant tools and approaches for diagnosing animal infections is particularly important here (33, 65). In addition, the underlying assumption that removal or reduction of an animal disease (and producing more food or promoting less intensive food systems) leads to greater world food security (65) fails to account for the many stages and political interests that exist within and between farm production and human consumption, including their effects on the environment and society.

Importantly, the humanities (e.g. history and philosophy) and social sciences (e.g. anthropology, sociology, economics and political science), considered 'softer' by the 'hard' biomedical sciences, have often been marginalised in animal health research (66). This, in turn, has resulted in farmed animals, the social determinants of farmed animal health, and their effects on the local and global economy being somewhat overlooked, despite being key to informing sustainable animal health (and food) policy. If governments are serious about promoting sustainable development, ethics and world food security, then this must become a research priority.

Why we must bring these scientific concerns back into aquaculture

As aquaculture has developed, there have been drives to increase yields, improve feed conversion rates and generate greater levels of fish production. Aquaculture systems have so far been measured by productivity assessments that include the output of 'wet' live weight per unit of 'dry' feed, per unit of space and per unit of labour. These traditional measures used by the animal health sciences are based on market prices, which are poor indicators of production sustainability (61), and rarely include the costs of the food industry to the health and well-being of animals, the environment, and society.

Somehow, therefore, we need to find a balance between such costs and the noble vision of world food security, praised by international institutions (23). Aquaculture today is well placed to provide quality food at a reasonable price, through ethical systems of food production favouring the sustainable development of society. However, such a balance cannot be achieved without rethinking the status and expanding the *multiple* representations of farmed animal health and well-being in society.

La sécurité alimentaire mondiale, la mondialisation et l'élevage : débloquer les paradigmes dominants des sciences de la santé animale

C. Bellet & J. Rushton

Résumé
Dans cet article, les auteurs procèdent à un examen critique de l'élevage intensif et mettent en évidence, à la lumière de crises présentes et passées, la fragilité, le caractère non durable et l'incapacité de ce modèle agricole à contribuer à la sécurité alimentaire mondiale. L'argument central avancé par les auteurs est que l'élevage intensif favorise la rentabilité de l'industrie agro-alimentaire ainsi que la production et la commercialisation de denrées alimentaires bon marché, au détriment des animaux d'élevage, de l'environnement et de la société. L'article commence par un aperçu historique de la sécurité alimentaire suivi d'une analyse du rôle assigné, dans ce contexte, à l'élevage, aux animaux d'élevage et à la santé publique. L'évolution de la perception de la sécurité alimentaire est analysée au fil de diverses périodes d'instabilité, parallèlement à ses conséquences sur l'élevage, la santé et le bien-être des animaux. Les auteurs tentent ainsi d'explorer ce qui a, jusqu'à présent, manqué dans les discours dominants de la sécurité alimentaire et de l'élevage, et d'expliquer comment ces lacunes ont pu déterminer et être renforcées par les pratiques des sciences de la santé et du bien-être animal. Compte tenu de la croissance exponentielle du secteur de l'aquaculture, le but des auteurs est d'examiner de quelle manière une redéfinition du rôle et de l'intervention des sciences de la santé animale en élevage permettrait à celui-ci, et en particulier à l'aquaculture, de réellement contribuer à la sécurité alimentaire mondiale.

Mots-clés
Aquaculture – Durabilité – Élevage – Mondialisation – Production alimentaire – Science de la santé animale – Sécurité alimentaire – Sécurité alimentaire mondiale.

Seguridad alimentaria mundial, mundialización y producción animal: desentrañar los paradigmas dominantes de la ciencia de la sanidad animal

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Resumen
Los autores presentan un estudio crítico de la producción animal intensiva a la luz de una serie de crisis mundiales pasadas y presentes que ponen de relieve sus frágiles fundamentos, su carácter insostenible y la incapacidad de este modelo agrícola para garantizar la seguridad alimentaria del mundo. Uno de los argumentos centrales aquí expuestos es el de que la producción animal intensiva promueve la eficiencia de la industria agro-alimentaria, la producción de artículos básicos y la oferta de alimentos baratos a expensas de los animales de granja, el medio ambiente y la sociedad. Los autores empiezan repasando sucintamente la historia de la seguridad alimentaria mundial y examinando la función atribuida en este ámbito a la producción animal, los animales de granja y la salud pública. Después exponen la evolución de las concepciones relativas a la seguridad alimentaria mundial durante varios periodos de inestabilidad del mundo y las repercusiones que esas distintas formas de verla han tenido en la producción, la salud y el bienestar animales. Al mismo tiempo, tratan de determinar aquello que hasta ahora ha estado ausente del discurso sobre la seguridad alimentaria mundial y la producción animal, y explican cómo estos elementos faltantes influyen en el pensamiento científico sobre salud y bienestar animal y a la vez son influidos por él. En vista del crecimiento exponencial que de un tiempo a esta parte viene experimentando la acuicultura, los autores tienen por doble objetivo examinar las prácticas zoosanitarias de la producción animal y aprehender de qué

manera la ciencia de la sanidad animal podría ayudar eficazmente a la producción animal, y particularmente la acuicultura, a consolidar a largo plazo la seguridad alimentaria mundial.

Palabras clave
Acuicultura – Ciencia de la sanidad animal – Mundialización – Producción animal – Producción de alimentos – Seguridad alimentaria – Seguridad alimentaria mundial – Sostenibilidad.

References

1. Maye D. & Kirwan J. (2013). – Food security: a fractured consensus. *J. Rur. Stud*., **29**, 1–6. doi:10.1016/j. jrurstud.2012.12.0.

2. Tomlinson I. (2013). – Doubling food production to feed the 9 billion: a critical perspective on a key discourse of food security in the UK. *J. Rur. Stud*., **29**, 81–90. doi:10.1016/j. jrurstud.2011.09.001.

3. Kearney P. (2010). – Food consumption trends and drivers. *Philos. Trans. Roy. Soc. Lond., B, Biol. Sci*., **365** (1554), 2793– 2807. doi:10.1098/rstb.2010.0149.

4. Food and Agriculture Organization of the United Nations (FAO) (2006). – World agriculture: towards 2030/2050. FAO, Rome, Italy, 78 pp. Available at: www.fao.org/fileadmin/user upload/esag/docs/Interim_report_AT2050web.pdf (accessed on 12 April 2019).

5. Ritchie H. & Roser M. (2017). – Meat and seafood production and consumption. Our World In Data. Available at: https://ourworldindata.org/meat-and-seafood-productionconsumption (accessed on 12 April 2019).

6. Scanes C.G. (2018). – Animal agriculture: livestock, poultry, and fish aquaculture. *In* Animals and human society (C.G. Scanes & S.R. Toukhsati, eds). Academic Press, Cambridge, Massachusetts, United States of America, 133–179. doi:10.1016/B978-0-12-805247-1.00007-1.

7. European Commission (EC) (2017). – Agriculture and food: background on the EU food supply chain: an important economic sector. EC, Brussels, Belgium. Available at: http://ec.europa.eu/competition/sectors/agriculture/overview_en.html (accessed on 12 April 2019).

8. Wallinga D. (2009). – Today's food system: how healthy is it? *J. Hunger Environ. Nutr.*, **4** (3–4), 251–281. doi:10.1080/19320240903336977.

9. Vos E. (2000). – EU food safety regulation in the aftermath of the BSE crisis. *J. Consum. Pol.*, **23** (3), 227–255. doi:10.1023/A:1007123502914.

10. Casey D.K., Lawless J.S. & Wall P.W. (2010). – A tale of two crises: the Belgian and Irish dioxin contamination incidents. *Br. Food J*., **112** (10), 1077–1091. doi:10.1108/00070701011080212.

11. Huang X., Hites R.A., Foran J.A., Hamilton C., Knuth B.A., Schwager S.J. & Carpenter D.O. (2006). – Consumption advisories for salmon based on risk of cancer and noncancer health effects. *Environ. Res.*, **101** (2), 263–274. doi:10.1016/j.envres.2005.08.011.

12. Gilbert M., Xiao X. & Robinson T.P. (2017). – Intensifying poultry production systems and the emergence of avian influenza in China: a 'One Health/Ecohealth' epitome. *Arch. Public Hlth*, **75**, 48. doi:10.1186/s13690-017-0218-4.

13. Lawrence F. (2009). – The pigs' revenge. *Guardian*, 2 May 2009. Available at: www.theguardian.com/world/2009/may/02/swine-flu-pandemic-mexico-pig-farming (accessed on 12 April 2019).

14. Lawrence F. (2017). – Horsemeat trial shines light on key part of international fraud. *Guardian*, 26 July 2017. Available at: www.theguardian.com/uk-news/2017/jul/26/horsemeat-trialshines-light-international-fraud (accessed on 12 April 2019).

15. Leibler J.H., Otte J., Roland-Holst D., Pfeiffer D.U., Magalhaes R.S., Rushton J., Graham J.P. & Silbergeld E.K. (2009). – Industrial food animal production and global health risks: exploring the ecosystems and economics of avian influenza. *EcoHealth*, **6** (1), 58–70. doi:10.1007/s10393-009-0226-0.

16. Robson D. (2015). – Are any foods safe to eat anymore? Here is the truth. BBC Future. Available at: www.bbc.com/future/story/20151029-are-any-foods-safe-to-eat-anymore-heresthe-truth (accessed on 12 April 2019).

17. Rockström J. (2015). – What kind of Earth will future generations inherit? World Economic Forum, Global Agenda, Environment and Natural Resource Security, Governance for Sustainability. Available at: www.weforum.org/agenda/2015/10/what-kind-of-earth-will-future-generationsinherit/(accessed on 22 March 2019).

18. Food Standards Agency (FSA) (United Kingdom) (2016). – Our food future. FSA, London, United Kingdom, 82 pp. Available at: www.slideshare.net/bakeralan/our-food-futurefood-standards-agency-uk-gov (accessed on 12 April 2019).

19. Malthus T.R. (1798). – An essay on the principle of population. Printed for J. Johnson, in St. Paul's Church- Yard, London, United Kingdom, 126 pp. Available at: www.esp.org/books/malthus/population/malthus.pdf (accessed on 22 March 2019).
20. Shaw D.J. (2007). – World food security. A history since 1945. Palgrave MacMillan, Hampshire, United Kingdom, & New York, United States of America, 510 pp. doi:10.1057/9780230589780.21. Bourne J.K. Jr (2015). – The end of plenty. The race to feed a crowded world. W.W. Norton & Co., New York, United States of America, 416 pp.
22. United Nations (UN) (1960). – Provision of food surpluses to food-deficient peoples through the United Nations system. A/RES/1496. Available at: www.un.org/documents/ga/res/15/ares15.htm (accessed on 12 April 2019).
23. Food and Agriculture Organization of the United Nations (FAO) (1996). – World Food Summit: Rome Declaration on World Food Security, World Food Summit Plan of Action.
World Food Summit, 13–17 November, Rome, Italy. FAO, Rome, Italy. Available at: www.fao.org/docrep/003/w3613e/w3613e00.htm (accessed on 12 April 2019).
24. Rushton J. (2017). – Improving the use of economics in animal health – challenges in research, policy and education. *Prev. Vet. Med.*, **137** (Pt B), 130–139. doi:10.1016/j.prevetmed.2016.11.020.
25. Dietz T. & York R. (2015). – Animals, capital and sustainability. *Hum. Ecol. Rev*., **22** (1), 35–53. Available at: www.jstor.org/stable/24875147 (accessed on 12 April 2019).
26. Le Heron R.B. (1993). – Globalized agriculture: political choice. Pergamon Press, Oxford, United Kingdom, 235 pp.
27. Page B. & Walker R. (1991). – From settlement to fordism: the agro-industrial revolution in the American Midwest. *Econ. Geogr*., **67** (4), 281–315. doi:10.2307/143975.
28. Rogers E.M. (1988). – The intellectual foundation and history of the agricultural extension model. *Sci. Commun*., **9** (4), 492–510. doi:10.1177/0164025988009004003.
29. Goodman D. & Redclift M. (1989). – The international farm crisis. MacMillan, London, United Kingdom, 296 pp. doi:10.1007/978-1-349-10332-4.
30. McMichael P. (2009). – A food regime genealogy. *J. Peasant Stud.*, **36** (1), 139–169. doi:10.1080/03066150902820354.
31. Reardon T., Timmer C.P., Barrett C.B. & Berdegué J. (2003). – The rise of supermarkets in Africa, Asia, and Latin America. *Am. J. Agric. Econ.*, **85** (5), 1140–1146. doi:10.1111/j.0092-5853.2003.00520.x.
32. Sexsmith K. & McMichael P. (2015). – Formulating the SDGs: reproducing or reimagining state-centered development? *Globalizations*, **12** (4), 581–596. doi:10.1080/14747731.2015.1038096.
33. Bellet C. (2018). – Change it or perish? Drug resistance and the dynamics of livestock farm practices. *J. Rur. Stud.*, **63**, 57–64. doi:10.1016/j.jrurstud.2018.08.016.
34. Brassley P. (2000). – Output and technical change in twentiethcentury British agriculture. *Brit. Agric. Hist. Rev.*, **48** (1), 60–84. Available at: www.jstor.org/stable/40275614 (accessed on 12 April 2019).
35. Bate A. (2016). – UK dairy industry statistics. House of Commons Library Briefing Paper, No. **2721**, 20 January 2016. House of Commons Library, London, United Kingdom, 10 pp. Available at: https://researchbriefings.files.parliament.uk/documents/SN02721/SN02721.pdf (accessed on 12 April 2019).
36. National Chicken Council (United States) (2019). – About the industry, facts and figures: US chicken industry history. Available at: www.nationalchickencouncil.org/about-theindustry/history/ (accessed on 12 April 2019).
37. Bowers J.K. (1985). – British agricultural policy since the Second World War. *Agric. Hist. Rev.*, **33** (1), 66–76. Available at: www.jstor.org/stable/40275421 (accessed on 22 March 2019).
38. Mathera A.A.S., Hill G. & Nijnik M. (2006). – Postproductivism and rural land use: cul de sac or challenge for theorization? *J. Rur. Stud*., **22** (4), 441–455. doi:10.1016/j.jrurstud.2006.01.004.

39. Rosin C., Stock P. & Campbell H. (eds) (2012). – Food systems failure. The global food crisis and the future of agriculture. Earthscan Food and Agriculture Series. Routledge, Abingdonon-Thames, Oxfordshire, United Kingdom, 256 pp.
40. Kroodsma D.A., Mayorga J. […] & Worm B. (2018). – Tracking the global footprint of fisheries. *Science,* **359** (6378), 904–908. doi:10.1126/science.aao5646.
41. Food and Agriculture Organization of the United Nations (FAO) (2016). – The state of world fisheries and aquaculture. FAO, Rome, Italy, 227 pp. Available at: www.fao.org/3/i9540en/I9540EN.pdf (accessed on 12 April 2019).
42. Jennings S., Stendiford G.D. […] & Verner-Jeffreys D.W. (2016). – Aquatic food security: insights into challenges and solutions from an analysis of interactions between fisheries, aquaculture, food safety, human health, fish and human welfare, economy and environment. *Fish and Fisheries*, **17** (4), 893–938. doi:10.1111/faf.12152.
43. Rigby B., Davis R., Bavington D. & Baird C. (2017). – Industrial aquaculture and the politics of resignation. *Mar. Pol.*, **80**, 19–27. doi:10.1016/j.marpol.2016.10.016.
44. Nir O. (2003). – What are production diseases, and how do we manage them? *Acta Vet. Scand.*, **44** (Suppl. 1), S21. doi:10.1186/1751-0147-44-S1-S21.
45. Bocker S. (2012). – Science, salmon, and sea lice: constructing practice and place in an environmental controversy. *J. Hist. Biol.*, **45** (4), 681–716. doi:10.1007/s10739-011-9299-z.
46. McDevitt R.M., Brooker J.D., Acamovic T. & Sparks N.H.C. (2006). – Necrotic enteritis; a continuing challenge for the poultry industry. *World Poult. Sci. J.*, **62** (2), 221–247. doi:10.1079/WPS200593.
47. Pollan M. (2006). – The omnivore's dilemma: a natural history of four meals. Penguin Putnam, New York, United States of America, 480 pp.
48. Chirase N.K., Wayne Greene L., Purdy C.W., Loan R.W., Auvermann B.W., Parker D.B., Walborg E.F., Stevenson D.E., Xu Y. & Klaunig J.E. (2004). – Effect of transport stress on respiratory disease, serum antioxidant status, and serum concentrations of lipid peroxidation biomarkers in beef cattle. *Am. J. Vet. Res*., **65** (5), 860–864. doi:10.2460/ajvr.2004.65.860.
49. Brockmeier S.L., Halbur P.G. & Thacker E.L. (2002). – Porcine respiratory disease complex. *In* Polymicrobial diseases (Brogden K.A. & Guthmiller J.M., eds). American Society for Microbiology (ASM) Press, Washington, DC, United States of America, 446 pp.
50. Mennerat A., Nilsen F., Ebert D. & Skorping A. (2010). – Intensive farming: evolutionary implications for parasites and pathogens. *Evol. Biol.,* **37** (2–3), 59–67. doi:10.1007/s11692- 010-9089-0.
51. Auge M. & Herzlich C. (1995). – The meaning of illness: anthropology, history and sociology. Routledge, Abingdon-on- Thames, Oxfordshire, United Kingdom, 240 pp.
52. Nerlich B. (2004). – Risk, blame and culture: foot and mouth disease and the debate about cheap food. *In* The politics of food (M.E. Lien & B. Nehrlich, eds). Berg Publishers, Oxford, United Kingdom, 244 pp. doi:10.5040/ 9781350044906.ch-003.
53. Bustos B. (2015). – Moving on? Neoliberal continuities through crisis: the case of the Chilean salmon industry and the ISA virus. *Environ. Plann. C. Gov. Policy*, **33** (6), 1361–1375. doi:10.1068/c1316.
54. Spellberg B., Hansen G.R., Kar A., Cordova C.D., Price L.B. & Johnson J.R. (2016). – Antibiotic resistance in humans and animals. *NAM Perspectives,* Discussion Paper. National Academy of Medicine, Washington, DC, United States of America. doi: 10.31478/201606d.
55. Fort M. (2001). – Paying the price for cheaper food. *Observer*, 25 February 2001. Available at: www.theguardian.com/ lifeandstyle/2001/feb25/shopping.ruralaffairs (accessed on 12 April 2019).
56. Stock P. & Carolan M. (2012). – A utopian perspective on global food security. *In* Food systems failure: the global food crisis and the future of agriculture (C. Rosin, P. Stock & H. Campbell, eds). Earthscan Food and Agriculture Series. Routledge, Abingdon-on-Thames, Oxfordshire, United Kingdom, 114–127.

57. Aarset B. & Jakobsen S.-E. (2015). – Path dependency, institutionalization and co-evolution: the missing diffusion of the blue revolution in Norwegian aquaculture. *J. Rur. Stud.*, **41**, 37–46. doi:10.1016/j.jrurstud.2015.07.001.
58. Friedmann H. (1991). – Changes in the international division of labor: agri-food complexes and export agriculture. *In* Towards a new political economy of agriculture (W.H. Friedland, L. Bush, F.H. Buttel & A.P. Rudy, eds). Westview Press, Boulder, Colorado, United States of America, 65–93.
59. International Diabetes Federation (IDF) (2013). – Reforming the global food system to tackle diabetes and obesity. *Guardian*, 14 February 2013. Available at: www.theguardian.com/sustainable-business/reform-global-food-system-diabetesobesity-private-sector (accessed on 12 April 2019).
60. Blythman J. (2013). – Salt, sugar, fat: how the food giants hooked us by Michael Moss – review. *Observer*, 24 February 2013. Available at: www.theguardian.com/books/2013/feb/24/salt-sugar-fat-moss-review (accessed on 12 April 2019).
61. Fry J.P., Mailloux N.A., Love D.C., Milli M.C. & Cao L. (2018). – Feed conversion efficiency in aquaculture: do we measure it correctly? *Environ. Res. Lett.*, **13** (2), 024017. Available at: http://iopscience.iop.org/article/10.1088/1748-9326/aaa273/meta (accessed on 12 April 2019).
62. Floros J.D., Newsome R. […] & Ziegler G.R. (2010). –Feeding the world today and tomorrow: the importance of food science and technology. *Compr. Rev. Food Sci. Safety*, **9** (5), 572–599. Available at: www.ift.org/knowledge-center/read-ift-publications/science-reports/ift-scientific-reviewfeeding-the-world-today-and-tomorrow.aspx (accessed on 12 April 2019).
63. Rushton J., Bruce M., Bellet C., Torgerson P., Shaw A., Marsh T., Pigott D., Stone M., Pinto J., Mesenhowski S. & Wood P.L. (2018). – Initiation of global burden of animal diseases programme. *Lancet*, **392** (10147), 538–540. doi:10.1016/S0140-6736(18)31472-7.
64. Rushton J. & Gilbert W. (2016). – The economics of animal health: direct and indirect costs of animal disease outbreaks. *In* Proc. 84th General Session of the World Assembly of OIE Delegates. World Organisation for Animal Health (OIE), Paris, France, 67. Available at: www.oie.int/fileadmin/home/eng/Media_Center/docs/pdf/SG2016/A_84SG_9.pdf (accessed on 19 June 2019).
65. Bellet C., Green M.J., Bradley A.J. & Kaler J. (2018). – Short- and long-term association between individual levels of milk antibody against *Ostertagia ostertagi* and first lactation heifer's production performances. *Vet. Parasitol.*, **256**, 1–8. doi:10.1016/j.vetpar.2018.04.008.
66. Bellet C. (2019). – Antimicrobials and sustainable practice: why we must bring farmers back into the picture. *Gov. Eur. Quart.,* 8 February. Available at: www.governmenteuropa.eu/antimicrobials-animal-farming/92191 (accessed on 12 April 2019).